MARGIN MANAGEMENT AND PROCEDURES FOR U.S. NAVY SMALL CRAFT

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NAVAL SEA COMBAT SYSTEMS ENGINEERING STATION
COMBATANT CRAFT ENGINEERING DEPARTMENT
NORFOLK, VA

NAVSEACOMBATSYSENGSTA REPORT NO 60-196
MAY 1988

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FOREWARD

Weight and center of gravity margins are included in a weight report by the designer to cover the inherent limits of precision in initial weight estimates. Powering and hump/speed margins are included to account for inaccuracies in design calculations. Service Life allowances are for additions that will take place in the life of the craft. Other allowances are for items that lack a high degree of definition and are usually based on past experience. It is incorrect to omit an item from the weight estimate with the belief it will be covered by margins. These items should be accounted for. This report is intended as a guide for selecting and using margins in the design and construction of U.S. Navy craft under the jurisdiction of NAVSEACOMBATSYSENGSTA. Guidance is provided to assure the craft will meet the structural, stability and mission requirements. The values outlined in this document can be violated only with the written authorization (waiver) from NAVSEACOMBATSYSENGSTA, Code 60, and shall be included in the design history.

This document differs from past formal and informal policy by the more precise definition of margins and the incorporation of the Service Life Allowance for future growth of the craft in service.

The readers are assumed to have a thorough understanding of the boat design process and are aware of the need for integrity and accuracy of the weight estimate. Each design requires individual consideration of its unique features, unknowns and complexities.

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1.0 INTRODUCTION: MARGINS IN THE DESIGN PROCESS

The weight estimate plays an important role in the design process. It affects speed, draft, stability, seakeeping and almost every other aspect of the design either directly or indirectly. The weight estimate becomes more refined as the number of iterations around the design spiral increase. The level of detail increases between the early weight estimates and the finished craft report. This is due to lack of definition in the early stages of design and the usual evolution of the design as it progresses through the design process. Ideally, the application of proper margins will assure accuracy of the estimates. If the craft is found to exceed an acceptable weight at some point in the design, the craft will have to be redesigned or the design process stopped. The design process should not continue with a flawed design. At this point, alternatives such as reduced payload and speed or other reduced mission capabilities trade-offs should be identified and presented.

Weight margins are included in the weight estimate throughout the design process in an attempt to accurately reflect the finished craft to avoid inadequacies in the design. The weight margins reflect the degree of confidence that the designer has that the weight estimate will accurately reflect the finished product. The weight margin is greatest in the earlier design stages and decreases in the later design stages as the design becomes more refined and complete.

Similarly, other allowances are applied to the craft to ensure that the delivered craft meets the original design requirements. The craft, once in service, is very seldom the craft that the Navy has designed. It is common practice to change the configuration of the craft as missions vary, to correct errors, make general improvements and to incorporate new technology that was not available during the design of the craft, especially one that has a long procurement. The fleet, crew and individual sailors will make modifications

during the life of the craft in order to improve the mission performance of the craft and to make it more habitable. These modifications tend to increase the weight of the craft and raise the vertical center of gravity. Service Life Allowances, in addition to the design margins, are added to the weight estimate in an attempt to depict the craft in the fleet. These additional allowances differ from the design margins in that they remain constant in magnitude as the design progresses while the design margin decreases.

There are combinations of maximum weight and centers of gravity that the craft cannot exceed if the craft is to meet stability or mission requirements. One of these requirements may place restrictions on the craft. The designer must determine what the restrictions are. For example, a craft has a maximum weight, or a maximum weight and KG, or a weight and LCG that the craft can not exceed during the craft's entire life. The designer, and those responsible in the fleet after delivery, often must exercise considerable restraint to ensure that the craft does not exceed these limits.

Pressure to increase craft capabilities to meet increased mission requirements, tend to drive the weight of the craft up or shift the CG to an unacceptable location. It is not unusual for the weight of the craft to creep up to the limiting displacement and beyond or CG to shift to such a degree that drastic actions are required. This can happen during the design, construction and in-service phases of the craft's life. If this happens during any phase, it will be Code 60's responsibility to:

a. Recommend design/construction/modification be terminated.

b. Recommend allowing design/construction/modification to continue with a written waiver.

c. Recommend operation of the craft be suspended.

d. Recommend allowing continuing operation of the craft, if the craft is in service, with restrictions.

e. Recommend removal of added (unauthorized) equipment or systems.

Any recommendation or waiver must be in writing and signed by the Code 60 department head. A letter shall be forwarded to NAVSEA and a copy of the letter placed in the design history.

2.0 WEIGHT AND CENTER OF GRAVITY (CG) MARGINS

2.1 Weight and KG Margins

The design margins are typically taken as the summation of percentages of the individual 1 digit groups and the loads of the weight estimate produced at the end of the particular stage of design. The percentages are given in Table (1) for individual 1 digit groups for various stages of design. The Service Life Allowance given in Table (2) is a fixed percentage of the calculated condition with all applicable design margins. The design margins listed in Table 1 do not include the Service Life Allowances listed in Table 2. The design margins are applied only to those portions of a weight group which are uncertain, and not to those items which have had a margin already assigned or for which no margin is required. Selected margins should be appropriate to the quality of information available for each system, and not simply according to the status of the overall design. The margins may be reduced or increased if the designer feels there is a justification. If margins are reduced, a written authorization should be included in the design history as previously discussed.

TABLE 1. Suggested Weight and KG Margin to Remain at End of Each Design Phase

DESIGN PHASE WEIGHT MARGINS (%)

WEIGHT GROUP (Groups 1-7)	CONCEPT/ FEASI-BILITY	PRELIM-INARY DESIGN	NAVSEA CONTRACT DESIGN	BUILDERS[1] DESIGN	BUILDERS CONSTRUC-TION	BOAT[2] ALT.
100 ALUM	15	8	5	2	2	3
STEEL	15	8	5	2	2	3
GRP	20	10	6	2	3	3
WOOD	20	10	6	2	3	3
200 PROPULSION	15	9	6	2	2	3
300 ELECTRICAL	20	12	8	2	2	5
400 COMMAND AND SURVELLIANCE	20	12	8	2	2	5
500 AUXILIARY	20	12	8	2	2	5
600 OUTFIT	20	12	8	2	2	5
700 ARMAMENT	10	5	3	2	2	2
LOAD ITEMS[3,4]	15	5	3	0	0	2

KG MARGINS (FEET)

CRAFT LEVEL KG MARGIN	0.50	0.30	.15	0.00	0.00	0.00

NOTES:

1 Builders Design Margin is to be allowed for the builder for first time boat construction and for reprocurement of boats over 50' in length.

2 Alterations designed for performance by the forces afloat are usually done in such sufficient detail that no margin should be required. These margins should be used when BOATALT design is such that margins are applicable.

3 Applied to those items which are not specifically called out or whose weight is not given in the craft's mission profile. Stores would generally have a 15 percent design weight margin in the concept/feasibility phase. However, if it was specified that the craft would carry an item, such as a battle tank, the battle tank's weight would not have a design weight margin.

4 Fuel is calculated with weight and power margins. This calculation should include the tankage volume margin (see Table 4).

TABLE 2. Service Life Allowance

Weight or KG	Service Life Allowance
Weight for structure, performance, and stability	5% of predicted Weight in any condition of Loading
KG for craft with deckhouse	0.5 feet
KG for craft without deckhouse	0.3 feet

Note: The margins listed in Table 1 do not include the Service Life Allowance required and detailed in Table 2.

2.2 Longitudinal Center of Gravity (LCG) Margin

LCG location has a significant effect on planing boat performance. In addition LCG (trim) impacts damaged stability and hoisting conditions. For this reason, variants of LCG and their impact should be analyzed carefully in the feasibility and preliminary designs and adverse effects corrected before contract design commences.

In feasibility and preliminary design, a range of LCG positions ($\pm$ 2% of Length Between Perpendiculars (LBP) for feasibility and $\pm$ 1% of LBP for preliminary) should be considered for its effect on performance and stability. This effort informs the designers of the various impacts of LCG on the craft as it progresses from feasibility to preliminary and contract design. This will inform the designer of maximum limitations on LCG with the current hull form relative to planing condition and stability. The designers should then be aware of LCG problem areas before they reach contract design and necessary equipment, arrangement, or hull form changes made.

A range of LCG of ± 0.5% LBP should be analyzed during the contract design phase to account for any LCG changes that may take place in building or after construction due to various tank loadings or service life modifications. If the craft can not satisfy all requirements within these LCG ranges, then the actions previously mentioned should be implemented.

3.0 MARGINS OTHER THAN WEIGHT OR KG

3.1 Powering Margin

Craft should be designed to meet the maximum specified speed in the designated sea-state. The resistance of the craft should be calculated at the Full Load Displacement with all applicable margins including Service Life Allowance.

If all known elements of resistance and propulsion can be carefully evaluated then a 5% power margin should be sufficient in each of the NAVY's design phase.

This 5% power margin is to allow for potential errors in the methods used for calculating resistance or errors in model test scaling. This margin does not allow for extra power to account for hull fouling or engine degradation with age. If the above is desired, an extra margin should be applied, typically 5%.

Special cases such as super-cavitating propellers, surface piercing propellers and new production waterjets will have to be evaluated separately and will be cause for a larger power margin. This margin will be selected and documented in the design history. A margin of 8% in each of the NAVY's design phases is given as a guide.

If in a design stage, model tests or full scale data is available for similar craft with approximately the same displacements and centers, these values may be reduced to 2 percent for conventional powering and 4 percent for special cases.

3.2 Hump Speed/Thrust Margin

When designing high speed craft, the resistance at hump speed may become the critical design criteria. Resistance should be calculated in the design sea state and should include head wind drag which is appropriate to the sea state. Thrust required for these craft, at hump speed, should be calculated at the appropriate engine rating with the craft at Full Load with all applicable margins including Service Life Allowance. The calculated thrust margin for hump speed drag shall be as shown in Table 3. This margin is for hump speed only and should not be combined with the powering margin. In establishing the thrust margin at hump speed, calculations may assume propulsor "optimized" for the hump speed condition as long as this optimization does not alter the power train or propulsor geometric envelope, (i.e., propeller pitch may be varied but not propeller diameter, waterjet nozzle diameter may be varied but not the waterjet housing or inlet).

3.3 Miscellaneous Margins

Other margins and allowances to be used for design purposes are given to ensure that the boat in service will meet the original design requirements. Table 4 lists these other applicable margins, and Table 5 lists the Service Life Allowance.

TABLE 3. Hump Speed/Thrust Margins

Craft Type	Margin[1]	Margin[2]
Planing	10	25
SES	25	25
SWATH	15	25
Semi-Displacement	10	25

1 Use this margin for all craft using conventional propulsors.

2 Use this margin for craft using propulsors such as super-cavitating propellers, surface piercing propellers and new production waterjets.

TABLE 4. Other Margins to Remain at End of Design Phase

	Feasibility	Preliminary	Contract
Tankage Volume:			
Except Fuel[1]	5%	0%	0%
Fuel[1]	5%	5%	3%
Arrangeable Deck Area:	10%	0%	0%
Hull Volume:	5%	0%	0%
Electrical Power:	20%	10%	0%

[1]Note: It should be noted that these margins are to be in addition to calculations which include considerations such as liquid expansion, internal piping, structure deductions and height of suction line.

TABLE 5. Other Service Life Allowances

Electrical Power: 20%

Note:

In sizing a single generator electric plant, the calculated maximum electric load plus these design margins and allowances shall be met with the generator not exceeding 90% of its rated capacity.

Typically for craft with more than one generator, the calculated maximum electric load plus these design margins and allowances shall be met with one generator out of service. The remaining generator(s) should not be loaded in excess of 90% to allow for distribution system load unbalance during parallel operation.

4.0 CORRECTIONS TO CRAFT KG OR RIGHTING ARMS OTHER THAN MARGINS: FREE SURFACE

Free Surface effect must be taken into account when performing stability calculations. Free Surface in a craft causes a reduction in virtual GM and in craft stability.

Either of two options can be considered to account for this effect:

1) The free surface correction to KG can be calculated at Full Load using the maximum inertia of each tank. This inertia is then applied to all other load conditions for calculating the free surface correction to the KG.

2) An actual free surface calculation can be run in lieu of using (1) above. If this is done, calculate at a minimum the free surface correction at 5%, 25%, 50%, 75% and 95% of tank capacity and perform a stability analysis at each condition. This can be done using the BSTAAF computer program.

APPENDIX A

MEMORANDUM: MARGIN MANAGEMENT AND PROCEDURES DOCUMENT

Ser 61/M123
8 Mar 88

MEMORANDUM

From: Code 61 G3-9
To: Code 62,63
Via: Code 60 3/11/88

Subj: MARGIN MANAGEMENT AND PROCEDURES DOCUMENT

Encl: (1) Final draft copy of "Margin Management and Procedures for U.S. Navy Small Craft"

Ref: (a) NAVSEAINST 9096.6, 55W2, Ser 7 of 21 Feb 88
(b) NAVSEAINST ltr PMS300B/CAD Ser 374 of 12 Apr 83
(c) NAVSEA Memo for Conform Design Margins 50151/MRB Ser/112 of 16 May 84
(d) NAVSEA Memo Ser 00/6U300.255 of 19 Aug 86
(e) NAVSEA ltr 9583 OPR:3004 Ser 3004/1118 of 9 Oct 86
(f) NAVSEAINST 9096.5B, OPR55W2 of 7 Dec 87
(g) NAVSEA ltr OPR30041 Ser 300/40005 of 7 Jan 88

1. Reference (a) through (g) provided instructions to us for revising and updating the margin management policy of this department. Previous editions and revisions to this document were lengthy (exceeding 33 pages) and contained information not necessary for the subject. The revision gives the basics required by the above references, but tailored to suit small craft.

2. Enclosure (1) allows waivers of these margins depending on the particular program and knowledge of the design. It also requires that we recommend cancellation of programs where we see problems arising that can not be resolved.

3. This revised document assumes the readers have a thorough understanding of boat design process and of each craft's unique features, unknowns and complexities. Designers are to be aware that margins are not to cover items left out of weight reports but are due to limits in precision of the weight estimate at the particular stage.

4. The margin percentages given in Table 1 of enclosure (1) reflect those values previously stated in the original documents. The KG growth margins listed are changed from percentages of KG calculated to fixed values to be applied and reflect a slight reduction in requirements.

5. The Service Life Allowances given in Table 2 of enclosure (1) are new to this document but are now considered requirements for this department (see references). We have allowed for variation in hull types to suit this office's requirements.

6. Tables 3 and 4 of enclosure (1) represent information from previous documents except that:

a. Arrangeable deck area requirements were increased in the Feasibility stage.

b. Electric powering sizing requirements were reduced to agree with references.

c. Hull volume has been added to the Feasibility stage.

7. Powering and Hump Speed/Thrust Margins are given for guidance. Powering margin has been reduced from previous documents while the Hump Speed/Thrust Margin is the same as previously.

8. LCG margin definition has been increased.

9. Comments are requested by 20 March 1988. Any questions on weight or KG/LCG margins should be directed to G. Hatchell, R. Wilson or J. Almeter. Any questions on powering and Hump Speed/Thrust Margins should be directed to L. Codega, J. Almeter or D. Rowland. It is requested that final written remarks or comments be forwarded to Code 61, E. Lash.

E. G. Hatchell

E. G. HATCHELL

APPENDIX B

CONFERENCE REPORT: MARGIN MAMAGEMENT; POWERING AND HUMP SPEED/THRUST MARGINS

Conference Report

Date: 5 May 1988

Subject: Margin Management Report; Powering and Hump Speed/Thrust Margins

Attendees: Don Blount
Steve Denny
Frank Cirer
Mark Hoggard
Gordon Hatchell
Rich Wilson
Mac Whitford

Background:

A discussion was held to discuss the Powering and Hump Speed/Thrust Margin Section of the final draft of the Margin Management Report.

Results:

1. The Powering Margin section to remain as is.

2. The Hump Speed/Thrust Margin section was re-written and a new Table added to the report. The new Table bacame Table 3. The existing Tables in the draft report were renumbered to suit.